conclude that there is a distant dark body around which the bright star and the dark companion producing eclipses revolve in a period of 130 years (NATURE, vol. xlv. p. 446). This conclusion has been greatly strengthened by recent investigation by Mr. Searle, of the relative places of Algol and comparison stars from observations made with the meridian circle at Harvard College (*Annals*, vol. xxix. 1893). The right ascension of the star appears to be increasing in general conformity with Chandler's prediction.

THE INSTITUTION OF MECHANICAL ENGINEERS.

THE forty-seventh annual general meeting of the Institution of Mechanical Engineers was held on the evenings of Thursday and Friday of last week, in the theatre of the Institution of Civil Engineers. There were two papers down for reading, as follows:—

"Research Committee on Marine Engine Trials. Abstract of results and experiments on six steamers, and conclusions drawn therefrom in regard to the efficiency of marine engines and boilers," by Prof. T. Hudson Beare.

"Description of the Grafton High Speed Steam Engine," by Edward W. Anderson, of Erith.

The reading and discussion of Prof. Beare's paper, together with the introductory proceedings, occupied both evenings, so Mr. Anderson's paper had to be adjourned until next meeting.

Upon the members assembling on Thursday evening, the 1st inst., the President, Dr. William Anderson, took the chair. Mr. Bache, the secretary, then read the annual report of the council, by which it appeared that the Institution continues to flourish, the income and membership having increased during the past year. After the reading of the report Dr. Anderson vacated the chair, his term of office of two years having expired, and the new President, Prof. Alexander B. W. Kennedy, F.R.S., was duly installed. After the usual votes of thanks, and a few complimentary speeches, the reading of Prof. Beare's paper was proceeded with.

As our readers are aware, the Research Committee on marine engine trials of this Institution has been for some time past engaged in making trials with different steam vessels. The reports of the committee on these trials have already been referred to in our accounts of former meetings of the Institution at which they have been read. Six vessels have been experimented upon altogether since the committee was formed. These ships have consisted of channel passenger vessels and cargo boats, the committee not having had yet an opportunity of experimenting upon an important ship of the ocean liner type.

The labours of the committee have been brought to a conclusion, for the present at any rate; and the paper of Prof. Hudson Beare was intended to give a summary of the results, and afford a basis of discussion thereupon. We are at a loss how to condense within the compass of space at our disposal the mass of data dealt with by the author of the paper. Perhaps the most lasting impression on one's mind, after going through the subject, is that no general conclusions, that can be compactly expressed, are to be drawn from the trials. The conditions of work required from marine engines in ships of different classes are so various that what is paramount virtue in one case becomes an unnecessary refinement in another. Thus in the cargo boats the first consideration is economy in fuel, to which nearly every other feature in the machinery is usually sacrificed. In order to carry cargo at a rate sufficiently low to enable the shipowner to compete, the coal bill must be light, and therefore we find in these vessels boilers lightly worked and speeds low. On the other hand, vessels that have to convey passengers must be speedy, and general economy has to be sacrificed to this end, the model of the vessels themselves being formed with the same purpose in view. Perhaps we cannot do better than quote some of the elements of design of the machinery, and some of the results attained during the trials, in order to illustrate these leading facts. We will take two of the ships tried—the *Iona*, a large cargo boat, and the *Ville de Douvres*, a paddle boat carrying mails and passengers between Dover and Ostend. The *Iona* is 275 feet long, 37.3 feet wide, 27 feet 7½ inches draught, and 4430 tons displacement. Her speed on trial was 8·6 knots. The *Ville de Douvres* is 271 feet long, 29 feet wide, 9 feet draught, and 1090 tons displacement. On her trial she made 17·1 knots. It will be seen, therefore, that the cargo boat is considerably over four times the displacement, and travels at about one-half the speed of the mail boat. As both craft are approximately the same length, the additional size and weight-carrying capacity of the *Iona* is made up by her greater beam, and also by her fuller ends. The engines of the *Iona* are of the three-stage compound, popularly, but erroneously, known as triple expansion engines. As a matter of fact the *Iona's* engines are 19-expansion, the steam being expanded nineteen times in passing through the three cylinders. The *Ville de Douvres* has ordinary two-cylinder compound engines, in which the steam is expanded but 5·7 times. The horse-power required to drive the 4430 tons of the bluff-ended *Iona* through the water was but 645·4 indicated, whilst the *Ville de Douvres*, modelled for speed, required 2977 indicated horse-power to enable her to get her 17 knots. Supposing each unit of power to be obtained in both ships at an equal expenditure of fuel, the figures quoted will show the price that has to be paid for speed; but there is a further item to the debit side of the coal bill in the case of the fast ship. In order to get high speed it is very desirable, indeed necessary, that machinery should be light, and light machinery, other things being equal, means a low figure of merit in regard to fuel economy. The *Iona* works, as stated, with 19 expansions, her boiler pressure being 165 lbs. above atmosphere; whilst the *Ville de Douvres* has boilers pressed only to 105 lbs. The result of this greater expansion of steam on the part of the cargo boat's engines, and the easy way in which her boilers are worked, enables each unit of power to be obtained on a consumption of 1·46 lbs. of coal per hour; whilst the *Ville de Douvres* required 2·32 lbs. of coal for each indicated horse-power exerted for an hour.

It is easy to see from these figures, which are fairly representative, that economy and speed cannot go hand in hand; the owner must select whether he would rather travel cheaply (in fuel) or quickly.

Pursuing the investigation of this branch of the subject, we find that the total weight of the machinery of the *Iona* is 202 tons, which gives 3·1 units of power per ton weight of machinery; whilst the total weight of the machinery of the *Ville de Douvres* was 361 tons, equal to 8·2 units of power per ton weight of machinery. With regard to space occupied, the engines of the two ships are not comparable, being paddle and screw engines respectively; but in boilers we find that the net volume required for each indicated horse-power with the *Iona* was 4·15 cubic feet, and with the *Ville de Douvres* 2·09 cubic feet; thus showing that space as well as weight may be gained by the sacrifice of fuel economy. In the discussion which followed the reading of the paper, Mr. Jeremiah Head, of Middlesborough, gave some interesting figures in regard to those cargo steamers generally known as "ocean tramps." He stated that the s.s. *Westoe*, a vessel of this class, had carried 3500 tons dead weight at a speed of 9 knots, the fuel burnt being at the rate of ·64 oz. per ton per nautical mile, or about one five-hundredth of a penny. Another ship, the *Oscar II.* of 4600 tons dead weight capacity, required a consumption of half an ounce of coal per ton per mile. Still another vessel steaming at 8·9 knots showed a similar fuel economy. The figures are striking, and easily remembered: half an ounce of coal for each ton carried one nautical mile.

The boilers of both the *Iona* and the *Ville de Douvres* are of a similar type, being the ordinary return tube marine boiler, but the proportions are somewhat different. Thus in the *Iona* the proportion of total heating surface to grate surface is 75·2 per cent; in the *Ville de Douvres* it is but 31·1 per cent. This large extension of the heating surface means both a heavier and more bulky boiler, as has been shown; but in the cargo boat this sacrifice of weight and space can be profitably made in order that the fullest amount of heat from the products of combustion may be absorbed by the water in the boiler. In the *Ville de Douvres* this heat is allowed to pass off by the chimney. If we turn to the record of funnel temperatures we find this fact borne out, the escaping gases in the *Iona* being 452° F. and in the *Ville de Douvres* 910° F., as far as could be ascertained. The coal consumed on a given area of grate in the two vessels does not vary greatly, it being 22·4 lbs. per hour in the *Iona*, and 31·3 lbs. per hour in the *Ville de Douvres*. The different proportions of grate to heating surface in the two ships will, however, be

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remembered. If we turn to the coal burnt per hour per square foot of heating surface we find it but 0·298 lbs. in the *Iona*, and 1·01 lbs. in the *Ville de Douvres*. With regard to evaporation, each square foot of heating surface in the *Iona's* boilers turned 2·73 lbs. of water into steam per hour; in the *Ville de Douvres* the corresponding figure was 9·02. The feed-water evaporated per lb. of fuel was 9·15 lbs. in the *Iona*, and 8·97 lbs. in the *Ville de Douvres*. Taking carbon values—that is, excluding incombustible ash—and reducing the results to an equivalent of evaporation from and at 212°, we find the corresponding figures to be 10·42 lbs. for the *Iona* and 9·94 lbs. for the *Ville de Douvres*, a by no means bad result for the latter vessel's boilers, considering the demand made upon them in other respects.

Turning to the engines of these two ships, we find that the efficiency of the *Iona's* engines was 17·1 per cent., whilst the *Ville de Douvres'* engines had an efficiency of 11·7 per cent. The weight of steam used in the main engines of the former vessel was 13·35 lbs. per indicated horse-power per hour, whilst in the *Ville de Douvres* there were required 20·77 lbs. of steam to produce one unit of power.

The figures we have quoted will be sufficient to give an idea of the scope of the paper. We have not space to go into the discussion upon the various causes of the variations in results; for these we must refer our readers to the Proceedings of the Institution, where also will be found an account of the long and interesting discussion which followed the reading of the paper.

The summer meeting will be held this year in Manchester, at the beginning of August.

ON THE MOTION OF BUBBLES IN TUBES.

EVERY student of physics has observed the motion of bubbles in tubes. Which of them has not used a big bubble to show the little ones their duty in clearing out the air when filling a barometer tube? Who has not spent his time and patience in whisking a spirit thermometer to drive a bubble out of the column? Mr. Trouton has recently communicated to the Royal Society the result of some researches on this subject. He has studied the behaviour of big bubbles and of little ones, of bubbles in large and small tubes, of bubbles of air in a liquid, and of one liquid in another, of bubbles in heavy and in light liquids, of bubbles in liquids of various degrees of viscosity and with various degrees of surface tension at their surfaces. From this enumeration it is evident that the number of different magnitudes involved is very great, and at the start it seemed almost hopeless to disentangle the effects due to each. The first matter to observe was that, as in other cases of fluid motion, two cases must be distinguished. These are the cases of slow motion and of quick motion. When the motion is slow the viscosity of the liquid causes the flow to be very simple. It entirely stops all whirling and swirling, such as is seen in the water behind a boat. When the motion is quick, on the other hand, the flow is very complicated. Whirls and swirls are set up, and the resistance is increased, owing to the increased energy that has to be communicated to the whirling and swirling liquid for each centimetre that the bubble moves. The slow kind may be described as viscous flow, and the quick as turbulent flow. The most interesting point observed in connection with the turbulent flow was that it was sometimes possible to *increase* the rate of flow by *increasing* the viscosity. Increasing the viscosity of a liquid generally makes it flow more slowly, but in some critical cases the increase of viscosity may produce more effect in decreasing the turbulence than in increasing the viscous resistance, and the result is to, on the whole, reduce the combined resistance so that the bubble moves more rapidly in the liquid of greater viscosity. Another matter that was of interest was the question of the size of the bubbles, and how it affected their rate of motion. Very long bubbles moved all at nearly the same rate, but short bubbles had a great variety of rates. Very small bubbles ran along ever so fast, while ones only a little larger went very much more slowly. These latter blocked up the tube much in the same way that a crowd blocks its own egress through a doorway. However, bubbles a little larger seemed to have more sense, for they shape themselves into a sharpish head, with the result that they can make their way along the tube more rapidly than smaller ones. Those a little larger again take up a dumb-bell sort of shape, and block the tube, and go more slowly again, though not so slowly as the smaller blocking bubbles. A little larger go somewhat more rapidly again, but as the bubbles are made longer the differences between the rates of the quick and slow sizes become rapidly less and less until pretty soon all go at the same rate, no matter how long they are. This alternation of speeds is evidently connected with the ripples that are formed at the head of the bubble as it passes through the liquid, much as a stick moving through water makes a series of ripples upon the surface. If the ripples are so long that the bubble has a pointed head it goes fast, if it has a blunt head it goes slowly. These ripples are in some cases very marked. Mr. Trouton found that when a bubble of oil was allowed to rise through water with which one fifty-thousandth part of caustic soda was mixed the ripples became quite a feature of the figure of the bubble. They at first extended as a series of rings round it, which, however, soon coalesced into a spiral wave, when the bubble rose rapidly through the liquid with a sort of corkscrew motion. If the tube were inclined the ripples were only formed on the lower surface of the bubble, the top surface floating up against the containing tube, and the ripples then looked like the feet of a caterpillar walking up the tube. This is not the only case in which surface tension motions simulate muscular actions, and it is an important question whether some of these actions are similarities or simularities.

The surface tension between the air and liquid if the bubble is an air bubble, and between the two liquids if the bubble is a liquid one, has a very important bearing on the rate of motion of the bubble, for it is owing to this surface tension that the bubble swells out and presses against the sides of the tube. In consequence of this, when the surface tension is large the bubble moves more slowly than with a small surface tension. It would take too long to explain all the considerations by which Mr. Trouton was led to conclude, by the dimensions involved, that the velocity could be expressed in a series of powers of $S/g\delta D^2$ when S is the surface tension, g the acceleration of gravity, δ the difference of density of the liquid and bubble, and D the diameter of the tube. This series is multiplied by $\mu/g\delta D^2$ where μ is the viscosity of the liquid. Two assumptions are made. First, that the viscosity of the material of which the bubble is made is negligible; and secondly, that the motion produced by the surface tension is negligible compared with the motion produced by gravity. The series he gets from his experiments represents the results as accurately as can be expected, considering that the bubbles varied in density from air to mercury, the viscosity of the liquid from 1 to 833, and the surface tensions from 2 to 370. The series Mr. Trouton gives for calculating the time, T, a bubble takes to move one centimetre is

$$T = \frac{A_1\mu}{g\delta D^2} + \frac{A_2\mu S}{g^2\delta^2 D^4} + \frac{A_2\mu S^2}{g^3\delta^3 D^6}$$

The values of the constants can be determined by the values he gives from experiments on glycerine whose density was 1·25 and superficial tension 63 dynes per centimetre.

$$\frac{A_1\mu}{g} = 1{\cdot}308,\quad \frac{A_2\mu}{g^2} = {\cdot}02322$$

and

$$\frac{A_3\mu}{g^3} = {\cdot}0009108.$$

The formula is unfortunately a very inconvenient one for using to calculate the quantity that enters into it, and which is the most difficult to determine, namely, the surface tension between the bubble and liquid. This method of determining surface tension is one of the very few by which it can be determined without knowing angles of contact, which are so very difficult to determine at all accurately. In this way Mr. Trouton has determined the initial surface tension to be 6·5 between a bubble of water and glycerine that was pretty rapidly dissolving it. The ripple method could hardly be applied to this case, and it is doubtful whether the jet method could be applied to the surface between two liquids.

In connection with the high power to which g is raised in the formula it is interesting to note how, by altering the acceleration on the liquid by impacts or by centrifugal force we can very much increase the rate at which a bubble passes along a tube. This seems to be part of the rationale of the methods by which a bubble in a spirit thermometer can be shaken or whirled up the column.

The whole subject is of considerable interest, and lends itself to experimental investigation with very simple apparatus. A

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